

Laboratory Evaluation

Vaisala Air Quality Transmitter

AQT530



Outline

1. Background
2. O₃
3. NO₂
4. CO

DRAFT

Background

Three **Vaisala Air Quality Transmitter AQT530** (hereinafter **Vaisala AQT530**) multi-sensor units (units IDs: 673, 885, 847) were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (01/14/2022 to 03/25/2022) under ambient environmental conditions. Following field testing, the units were subjected to further laboratory testing in the South Coast AQMD Sensor Environmental Test Chamber 2 (SENTEC-2) under controlled pollutant concentration, temperature, and relative humidity conditions.

Vaisala AQT530 (3 units tested):

- Gas Sensors: **Electrochemical; non-FEM**
- Each unit measures: O₃ (ppb), NO (ppb), NO₂ (ppb), CO (ppb), T (°C), RH (%)
- **Unit cost: \$3,500 as-tested (Price ranges from \$3,500-\$6,500 depending on sensor configuration and addition of PM sensor)**
- Time resolution: 1-min
- Units IDs: 673, 885, and 847



Reference instruments:

- O₃ instrument (**FEM, T400, Teledyne, San Diego, CA**); **cost: ~\$9,000**
 - Time resolution: 1-min
- NO_x instrument (**FRM, T200, Teledyne, San Diego, CA**); **cost: ~\$13,000**
 - Time resolution: 1-min
- CO instrument (**FRM, T300U, Teledyne, San Diego, CA**); **cost: ~\$15,000**
 - Time resolution: 1-min



FEM T400



FRM T200



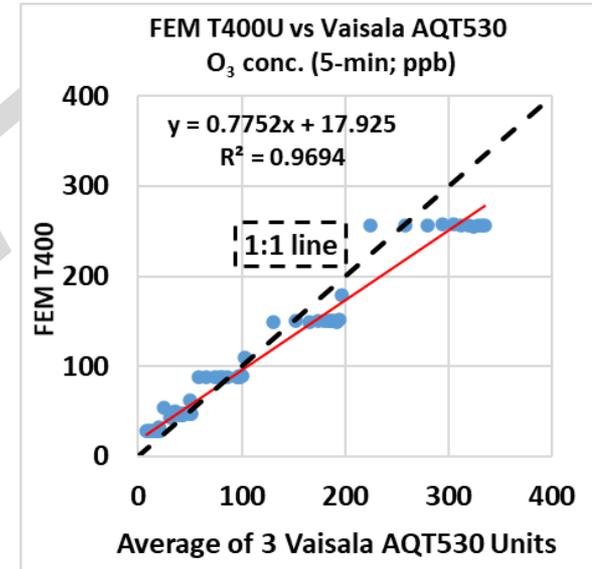
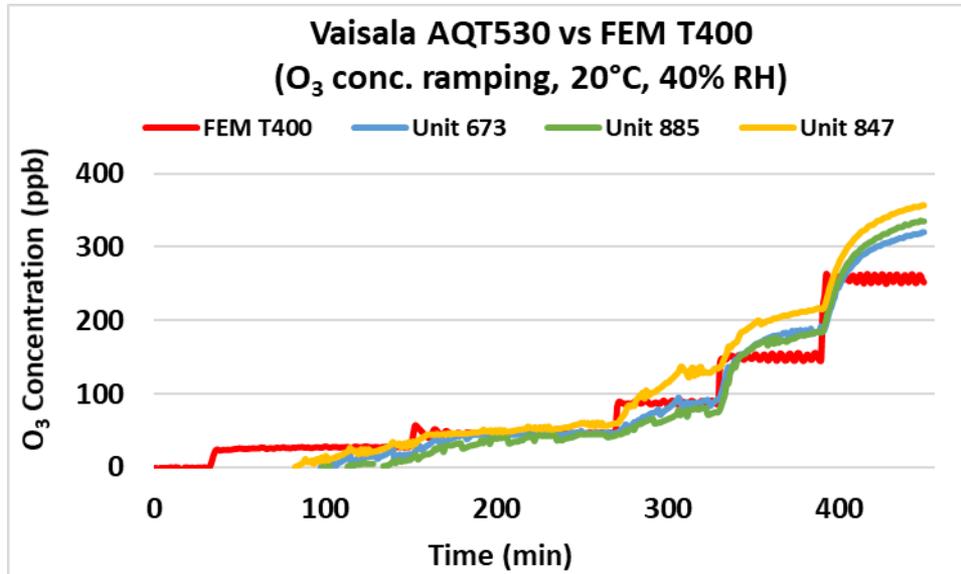
FRM T300U



1. **FEM T400 vs Vaisala AQT530**
2. **Accuracy, data recovery and intra-model variability**
3. **Precision**
4. **Climate susceptibility**
5. **Interferents**
6. **Discussion**

Vaisala AQT530 vs FEM T400 (O₃)

Coefficient of Determination



- The three Vaisala AQT530 sensors tracked the O₃ concentration variations recorded by FEM T400 instrument from ~30 to 250 ppb
- The Vaisala AQT530 sensors generally overestimated the O₃ concentration as recorded by the FEM T400 instrument
- The Vaisala AQT530 sensors showed very strong correlations with the corresponding FEM T400 O₃ conc. ($R^2 > 0.96$)

Accuracy: Vaisala AQT530 vs FEM T400 (O₃)

- Accuracy (20°C and 40% RH)

Steady State (#)	Sensor Mean (ppb)	FEM T400 (ppb)	Accuracy (%)
1	18.5	28.5	64.9
2	50.1	47.5	94.6
3	98.7	88.6	88.6
4	191.4	150.6	72.9
5	331.2	257.0	71.1

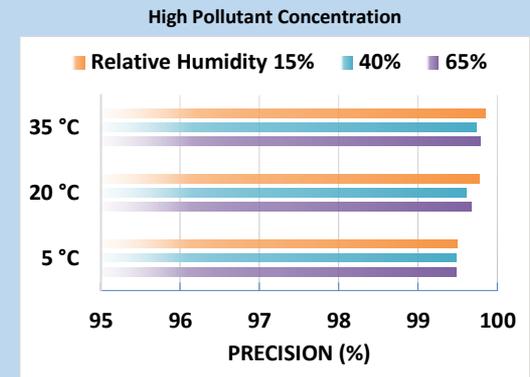
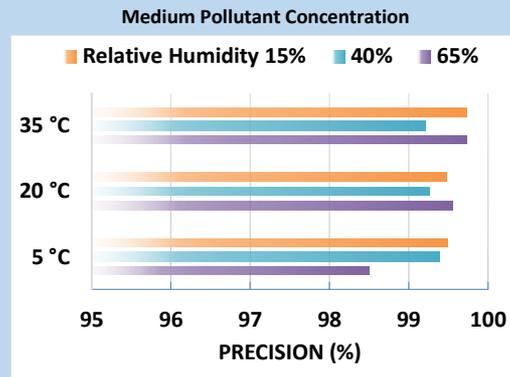
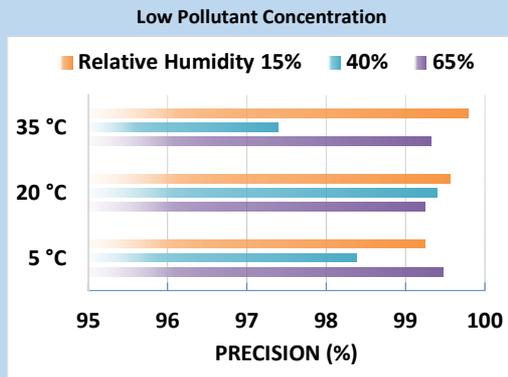
- Accuracy of the three Vaisala AQT530 sensors ranged from 64.9% to 94.6%. The accuracy decreased as O₃ concentrations increased, except at the first steady state. Overall, the sensors overestimated the FEM T400 O₃ measurements at 20°C and 40% RH.

Vaisala AQT530 Data Recovery and Intra-model Variability

- Data recovery for ozone measurements was 78.7%, 74.9%, and 82% for Units 673, 885, and 847, respectively
- Low to high O₃ concentration variations were observed between the three units at 20°C and 40% RH at low, medium and high O₃ concentrations as measured by the FEM T400.

Precision: Vaisala AQT530 vs FEM T400 (O₃)

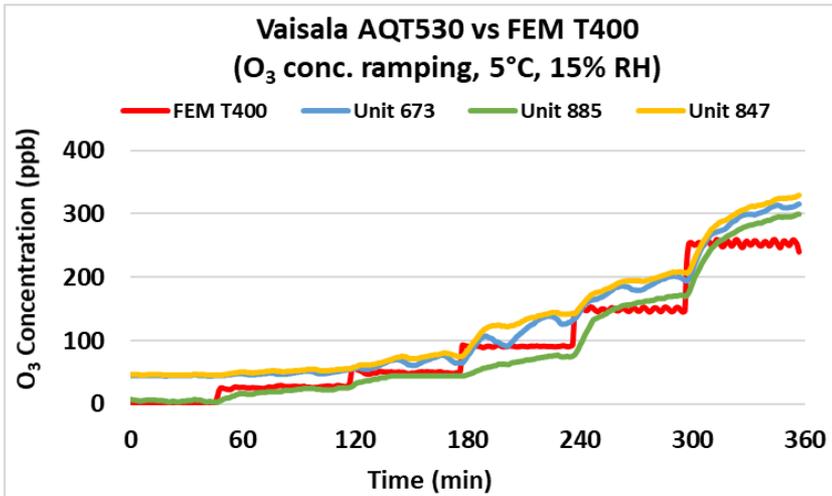
- Precision (Effect of O₃ conc., temperature and relative humidity)



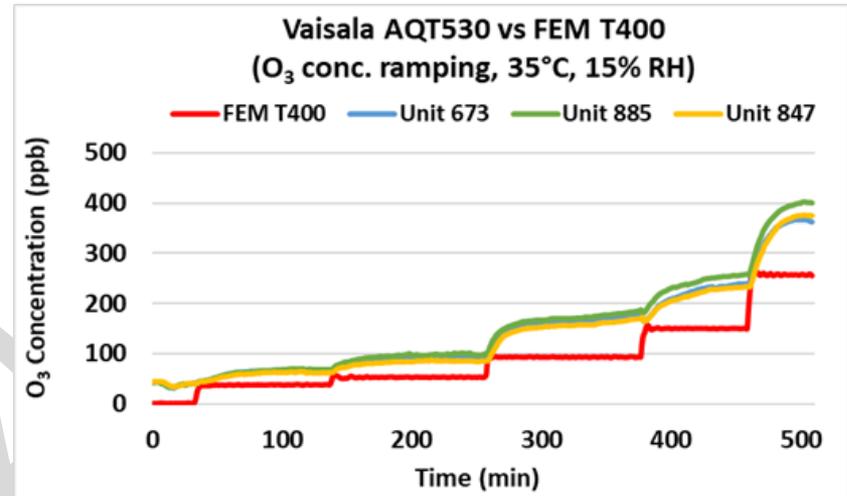
- Overall, the three Vaisala AQT530 sensors showed high precision for all combinations of O₃ conc., T, and RH.

Climate Susceptibility: Vaisala AQT530 (O₃)

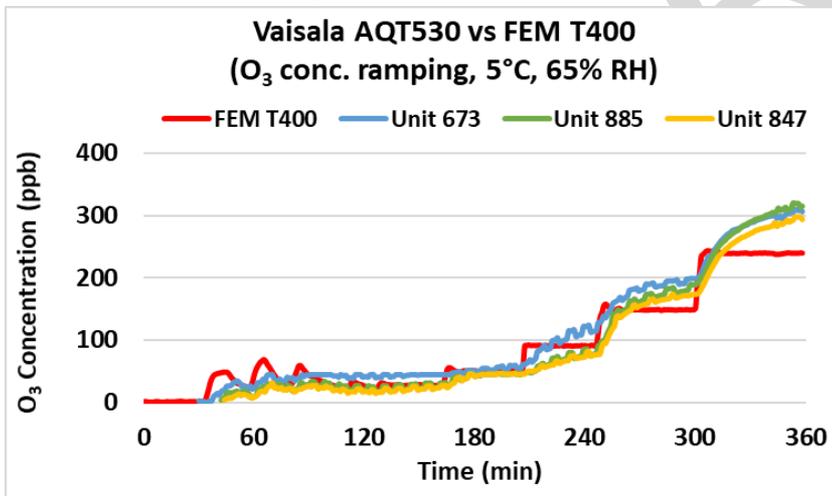
Low Temp-Low RH



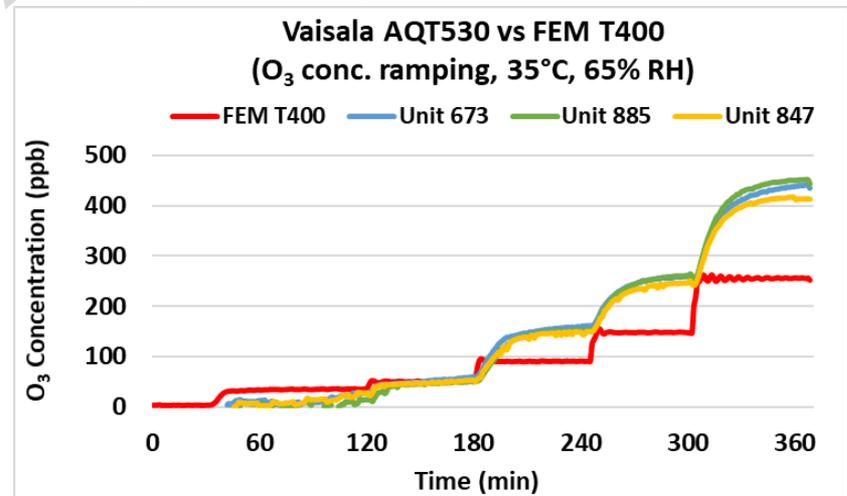
High Temp-Low RH



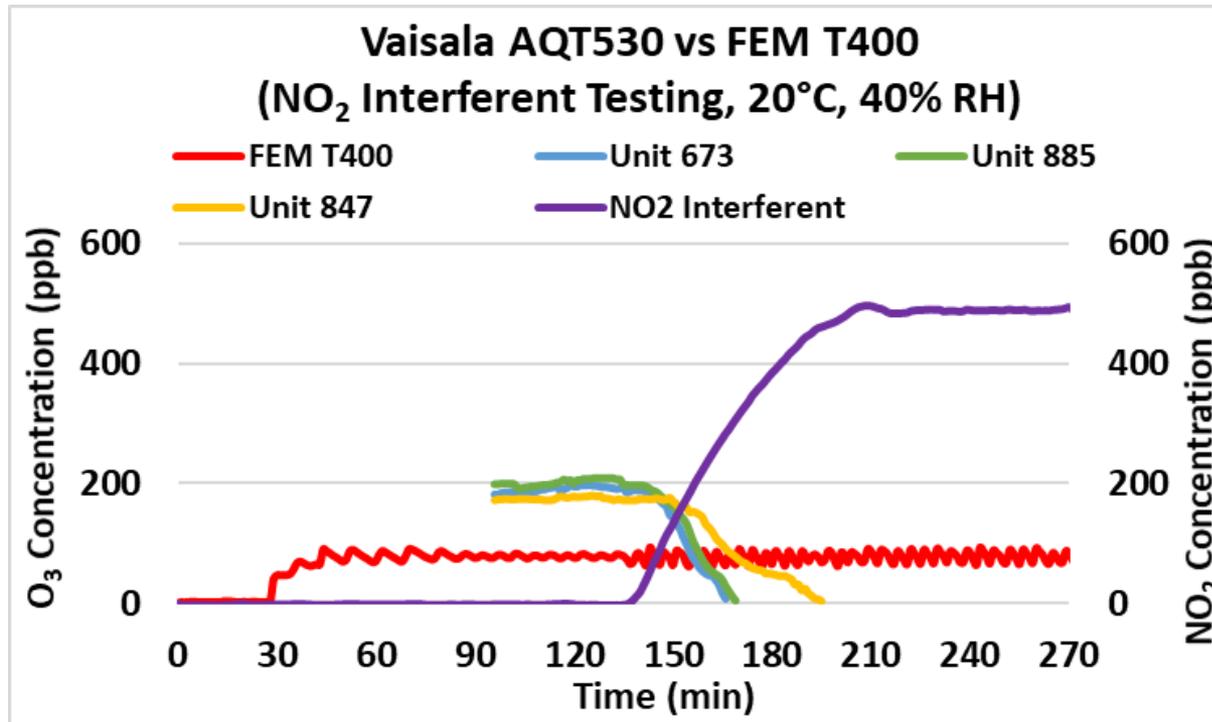
Low Temp-High RH



High Temp-High RH

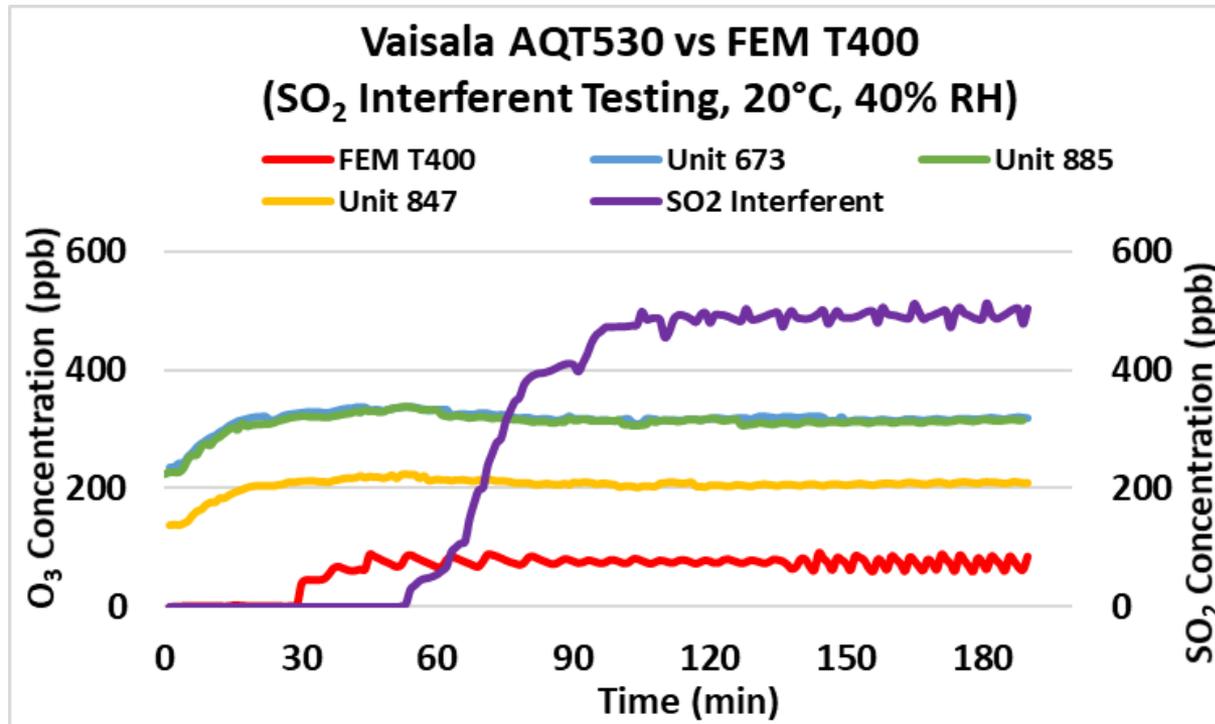


NO₂ Interferent: Vaisala AQT530 vs FEM T400 (O₃)



In the laboratory, the effect of NO₂ interferent is evaluated by exposing sensors to 500 ppb of NO₂ at 20°C and 40% RH while holding O₃ concentrations at 80 ppb. As shown in the figure, the FEM T400 was not affected by NO₂ while the sensors' ozone readings decreased or became negative with increasing NO₂.

SO₂ Interferent: Vaisala AQT530 vs FEM T400 (O₃)



In the laboratory, the effect of SO₂ interferent is evaluated by exposing the sensors to 500 ppb of SO₂ at 20°C and 40% RH while holding O₃ concentrations at 80 ppb. As shown in the figure, both the FEM T400 and sensors' O₃ measurements were not affected by SO₂.

Discussion: O₃

- **Accuracy:** The three Vaisala AQT530 sensors showed accuracy ranged from 64.9% to 94.6%.
- **Precision:** The three Vaisala AQT530 sensors exhibited high precision for all combinations of O₃, T and RH conditions.
- **Intra-model variability:** low to high O₃ measurement variations were observed among the three Vaisala AQT530 sensors at 20°C and 40% RH.
- **Data recovery:** Data recovery for O₃ measurements was 78.7%, 74.9%, and 82% for Units 673, 885, and 847, respectively.
- **Baseline:** At all conditions, FEM T400 O₃ instrument baseline was ranging from 0.5 to 2.4 ppb, while the sensors' baseline cannot be determined because the baseline data were either negative or not available.
- **Response time:** Response time could not be studied due to the system design of the chamber system. With a 1.6 m³ chamber volume and the max gas flow of 20 LPM, it was not possible to reach a high pollutant concentration within a short time.
- **Linear Correlation:** The three Vaisala AQT530 sensors showed very strong correlation/linear response with the corresponding FEM T400 O₃ measurement data ($R^2 > 0.96$).
- **Interferent (NO₂):** The three Vaisala AQT530 sensors' ozone decreased or became negative with increasing NO₂ concentrations at 20°C and 40% RH.
- **Interferent (SO₂):** The three Vaisala AQT530 sensors were inert to SO₂ at 20°C and 40% RH. When SO₂ was increased to 500 ppb, the sensors maintained similar readings compared to those before the SO₂ injection.

Discussion: O₃

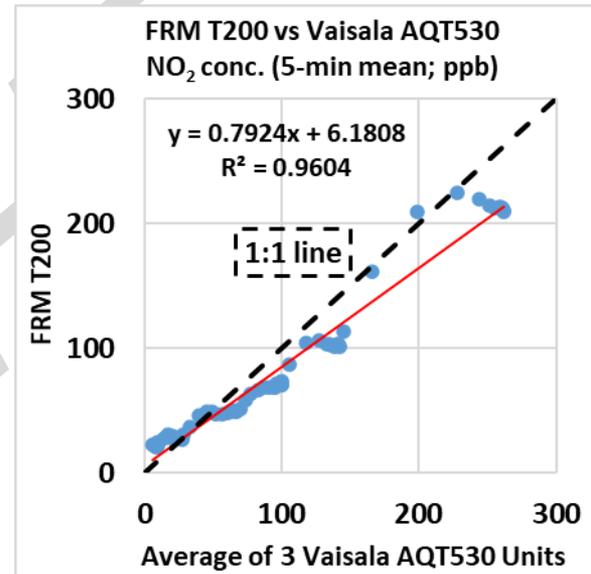
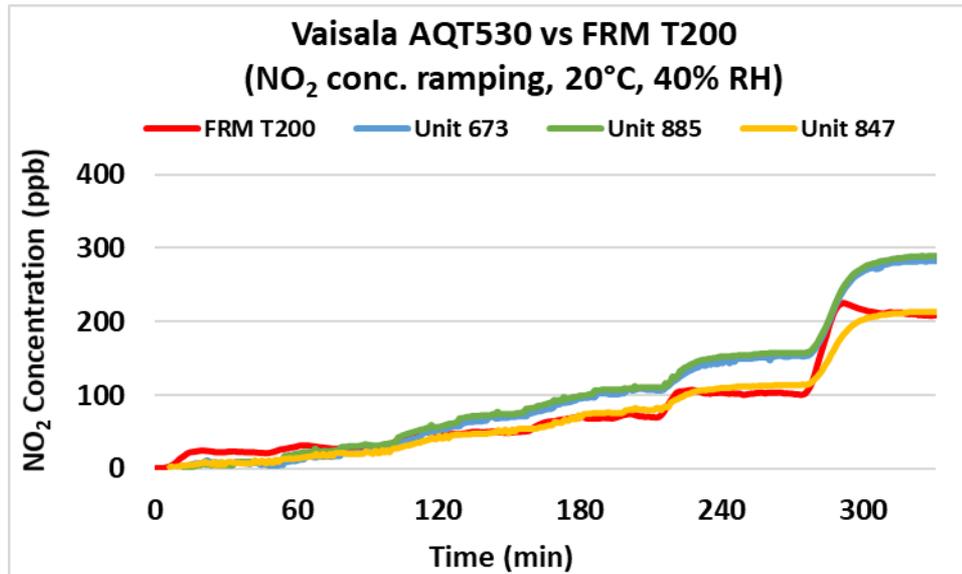
- **Measurement duration:** Vaisala AQT530 sensors report 1-min averaged values.
- **Measurement frequency:** Vaisala AQT530 sensors report 1-min averaged values. The obtained data was used as-is for calculation of statistics (e.g. data recovery, intra-model variability, mean, accuracy, precision), but condensed into 5-minute averages for linear correlation studies against the FEM T400.
- **Sensor contamination and expiration:** Prior to the laboratory evaluation, the Vaisala AQT530 sensors were tested in the field for two months. The O₃ laboratory studies lasted for about 17 days with intermittent non-operating periods and a storage period of ~ 11 months. For O₃ measurements, all three Vaisala AQT530 sensors maintained their functionalities and operated normally throughout the duration of the testing.
- **Concentration range:** 0-2 ppm O₃ concentration as suggested by the manufacturer. During the laboratory evaluation, the Vaisala AQT530 sensors were challenged with O₃ concentrations up to 250 ppb.
- **Climate susceptibility:** During the lab studies, temperature and relative humidity generally had little effect on the precision of O₃ concentrations as recorded by the Vaisala AQT530 sensors.
- **Response to loss of power:** Vaisala AQT530 sensors were powered through the entirety of the lab tests.

NO₂

1. **FRM T200 vs Vaisala AQT530**
2. **Accuracy, data recovery and intra-model variability**
3. **Precision**
4. **Climate susceptibility**
5. **Interferents**
6. **Discussion**

Vaisala AQT530 vs FRM T200 (NO₂)

Coefficient of Determination



- The sensors tracked the NO₂ concentration variations recorded by FRM T200 instrument
- Overall, the sensors generally overestimated the NO₂ concentration as recorded by the FRM T200 instrument

- The Vaisala AQT530 sensors showed very strong correlations with the corresponding FRM T200 NO₂ conc. ($R^2 > 0.96$)

Accuracy: Vaisala AQT530 vs FRM T200 (NO₂)

- Accuracy (20 °C and 40% RH)

Steady State (#)	Sensor Mean (ppb)	FRM T200 (ppb)	Accuracy (%)
1	24.8	27.6	89.9
2	64.9	49.6	69.2
3	98.6	71.3	61.8
4	141.4	102.6	62.2
5	261.1	210.9	76.2

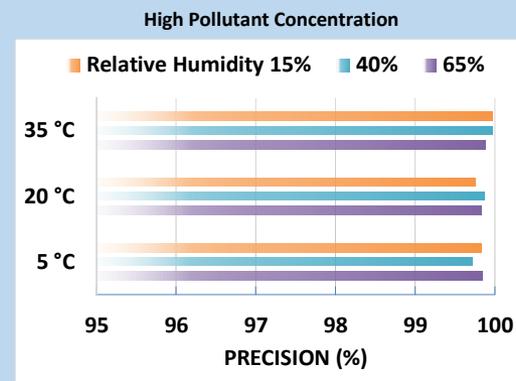
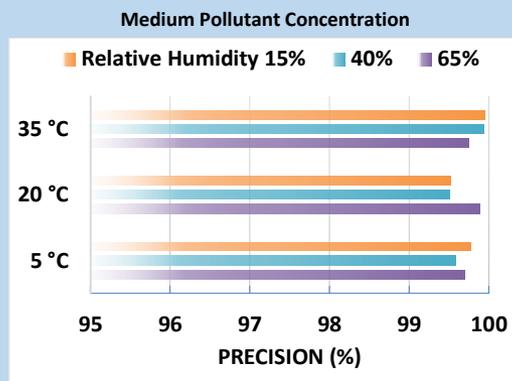
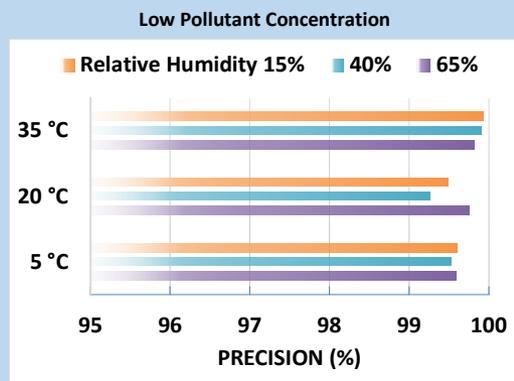
- Accuracy of the three Vaisala AQT530 sensors ranged from 61.8% to 89.9%. Overall, the sensors overestimated the FRM T200 measurements at all NO₂ concentrations but the first steady state at 20°C and 40% RH.

Vaisala AQT530 Data Recovery and Intra-model Variability

- Data recovery for NO₂ measurements was 96.4%, 96.1%, and 98.5% for Units 673, 885, and 847, respectively.
- Moderate NO₂ concentration variations were observed between the three units at 20°C and 40% RH at low, medium and high NO₂ concentrations as measured by the FRM T200.

Precision: Vaisala AQT530 vs FRM T200 (NO₂)

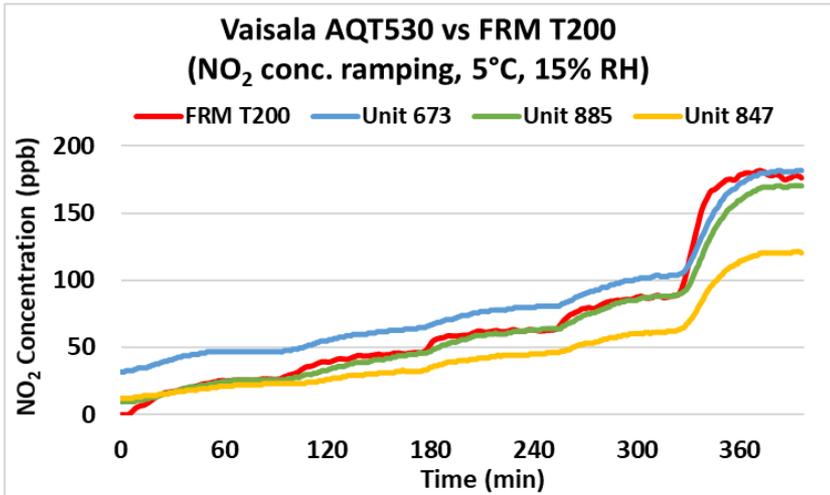
- Precision (Effect of NO₂ conc., temperature and relative humidity)



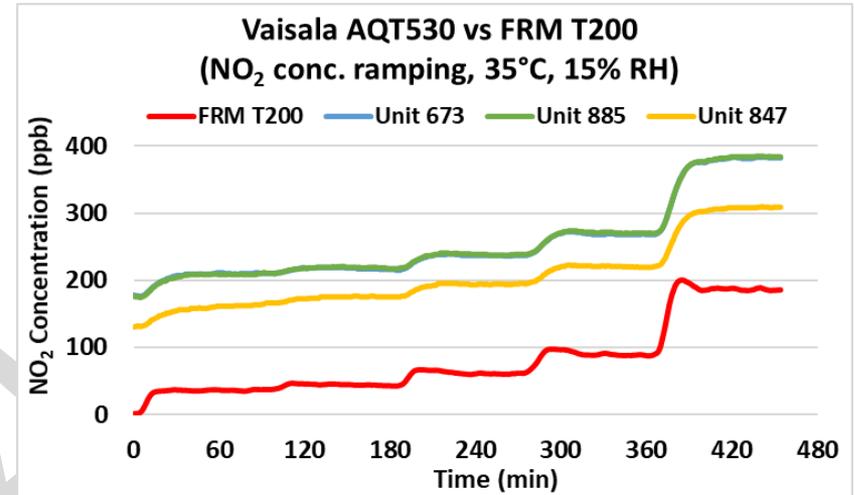
- Overall, the three Vaisala AQT530 sensors showed high precision for all combinations of NO₂ conc., T, and RH.

Climate Susceptibility: Vaisala AQT530 (NO₂)

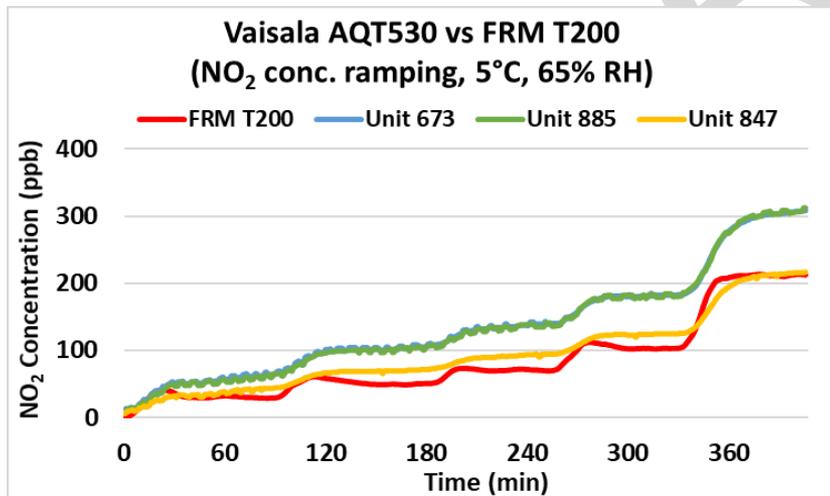
Low Temp-Low RH



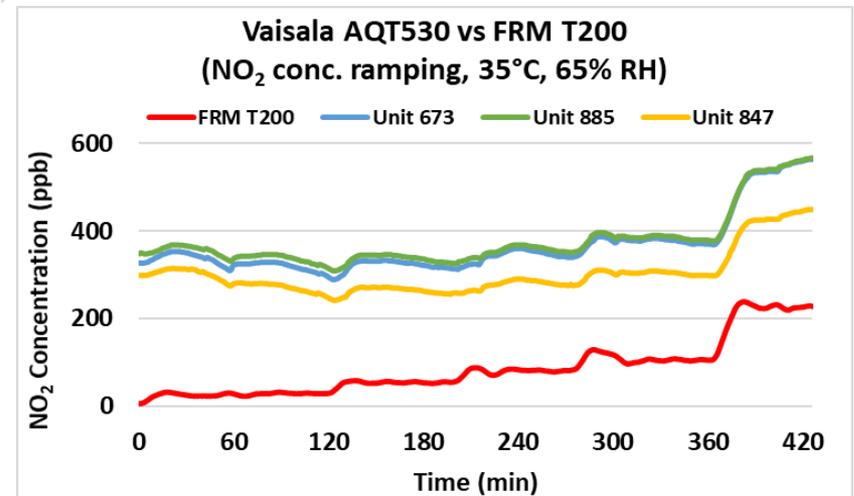
High Temp-Low RH



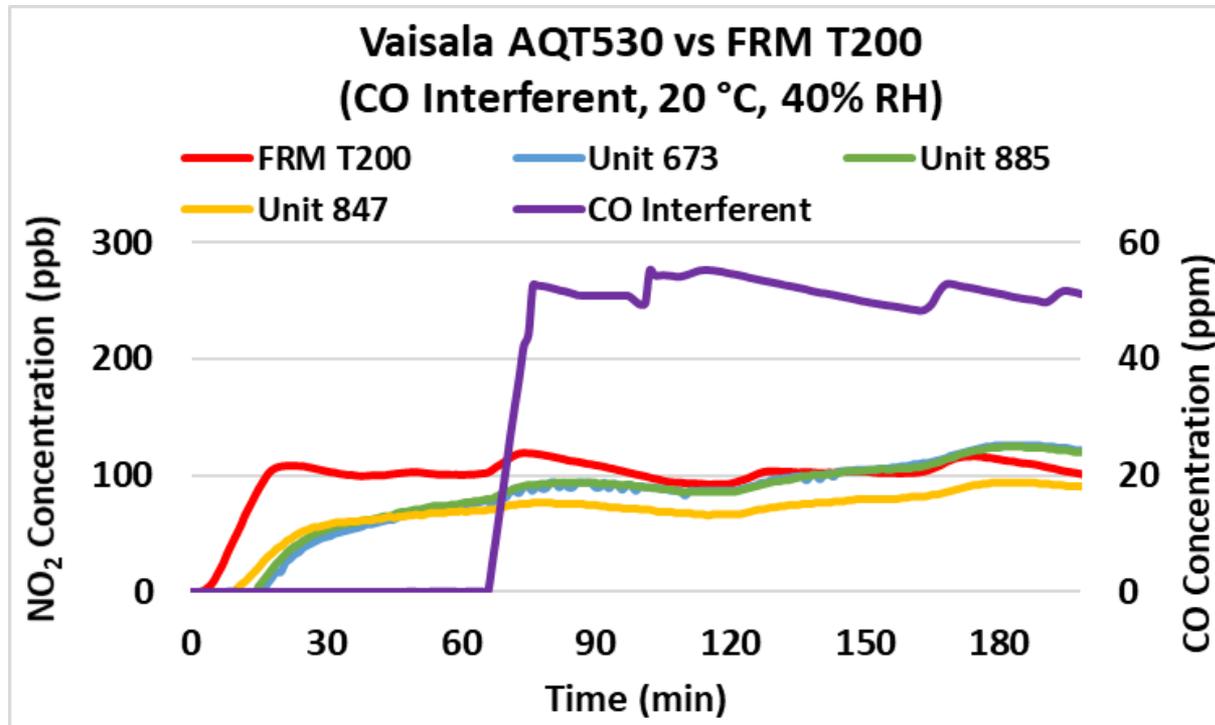
Low Temp-High RH



High Temp-High RH

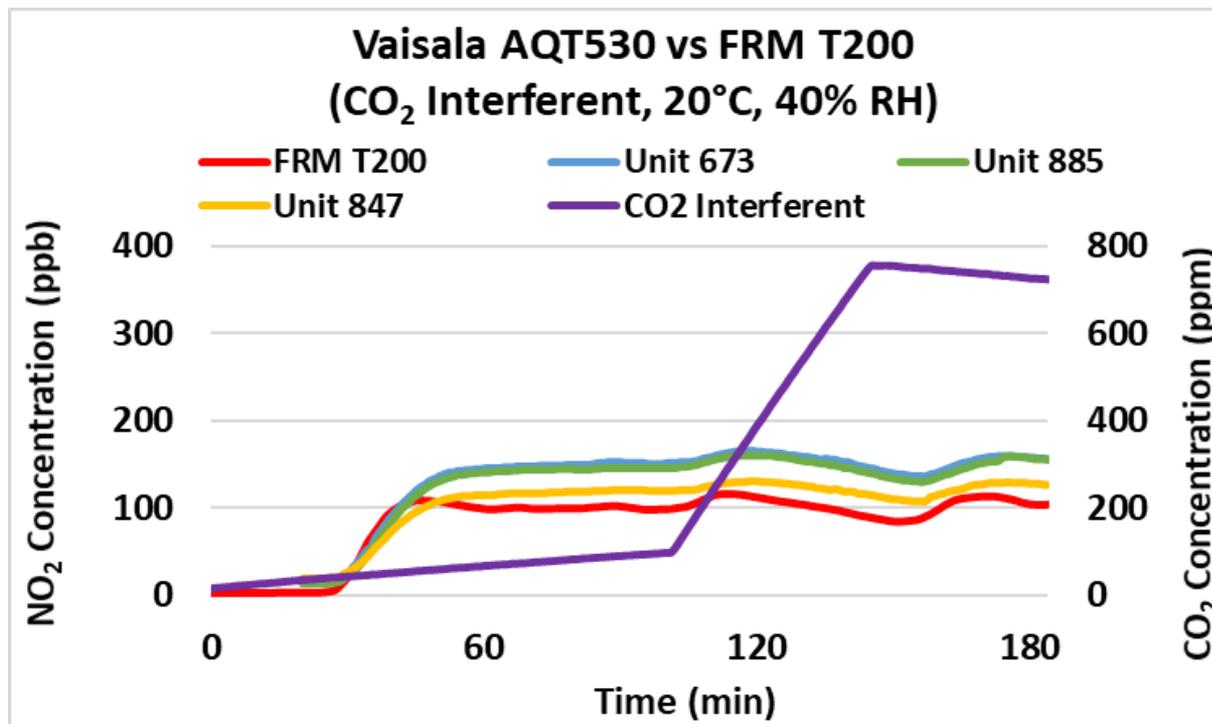


CO Interferent: Vaisala AQT530 vs FRM T200 (NO₂)



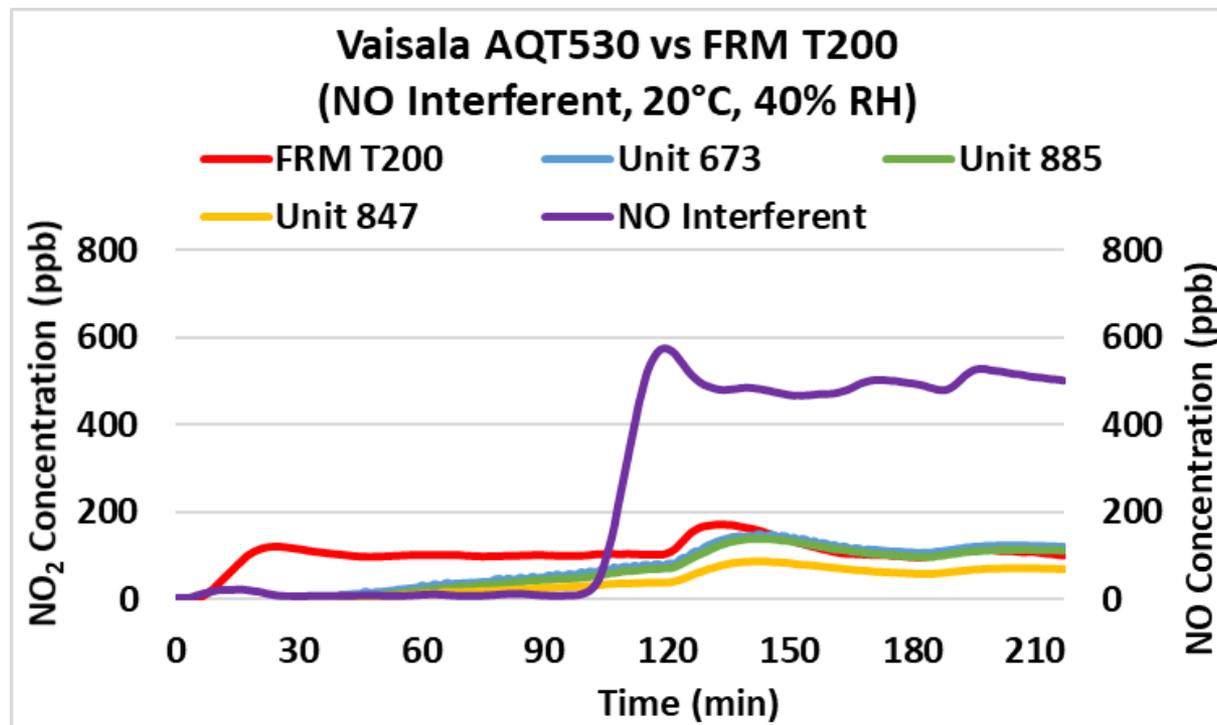
In the laboratory, the effect of CO interferent is evaluated by exposing sensors to 50 ppm of CO at 20°C and 40% RH while holding the NO₂ concentrations at 100 ppb. As shown in the figure, the FRM T200 and the sensors maintained their readings as the CO concentration increased to 50 ppm.

CO₂ Interferent: Vaisala AQT530 vs FRM T200 (NO₂)



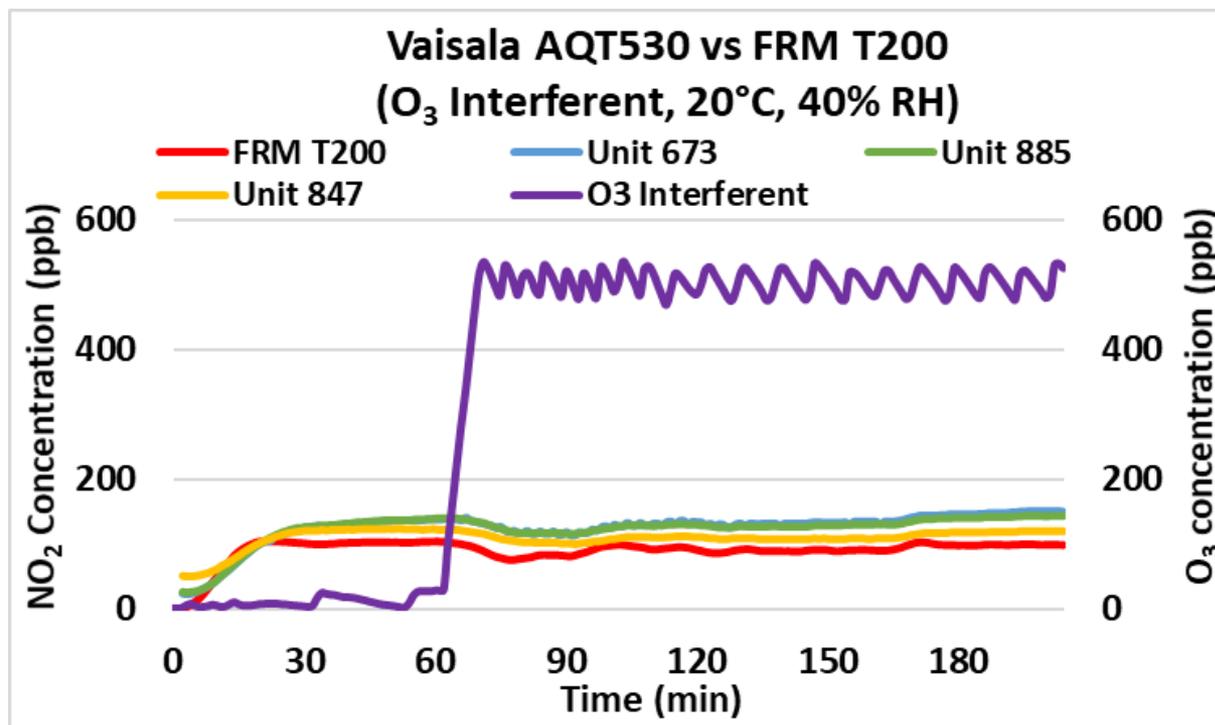
In the laboratory, the effect of CO₂ interferent is evaluated by exposing sensors to 750 ppm of CO₂ at 20°C and 40% RH while holding the NO₂ concentrations at 100 ppb. As shown in the figure, the FRM T200 and the sensors maintained their readings as the CO₂ concentration increased to 750 ppm.

NO Interferent: Vaisala AQT530 vs FRM T200 (NO₂)



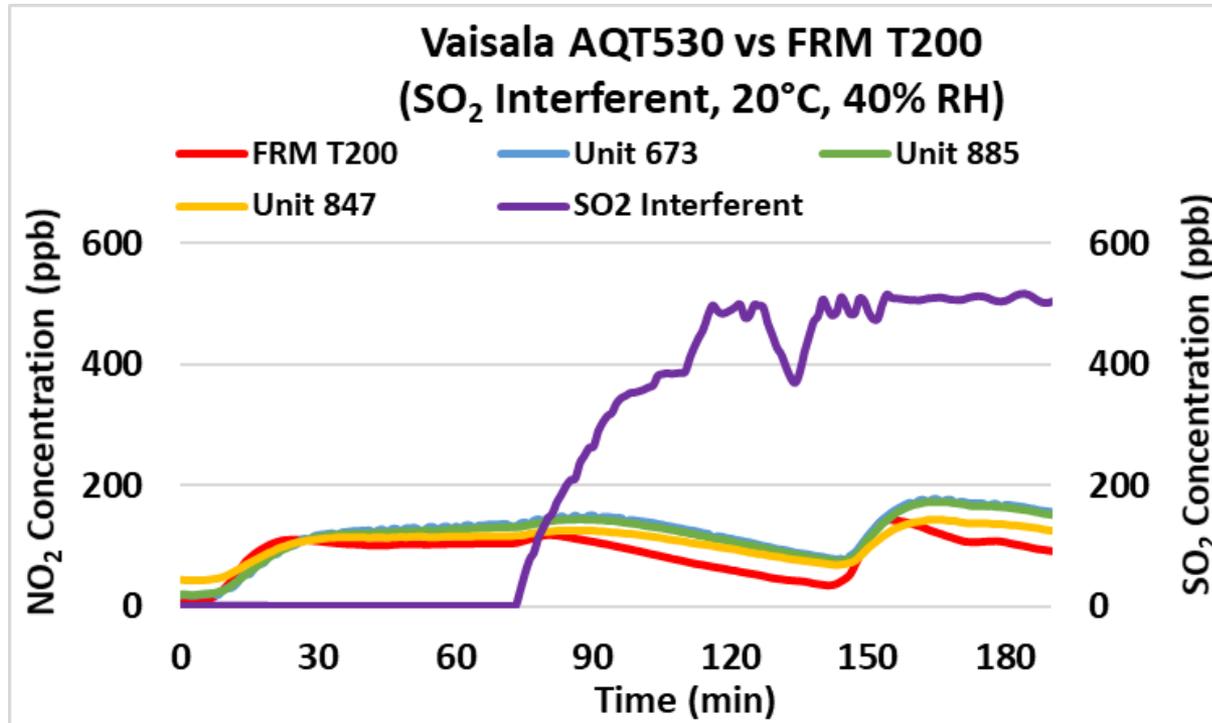
In the laboratory, the effect of NO interferent is evaluated by exposing sensors to 500 ppb of NO at 20 °C and 40% RH while holding the NO₂ concentrations at 100 ppb. As shown in the figure, the FRM T200 and the sensors maintained their readings as the NO concentration increased to 500 ppb.

O₃ Interferent: Vaisala AQT530 vs FRM T200 (NO₂)



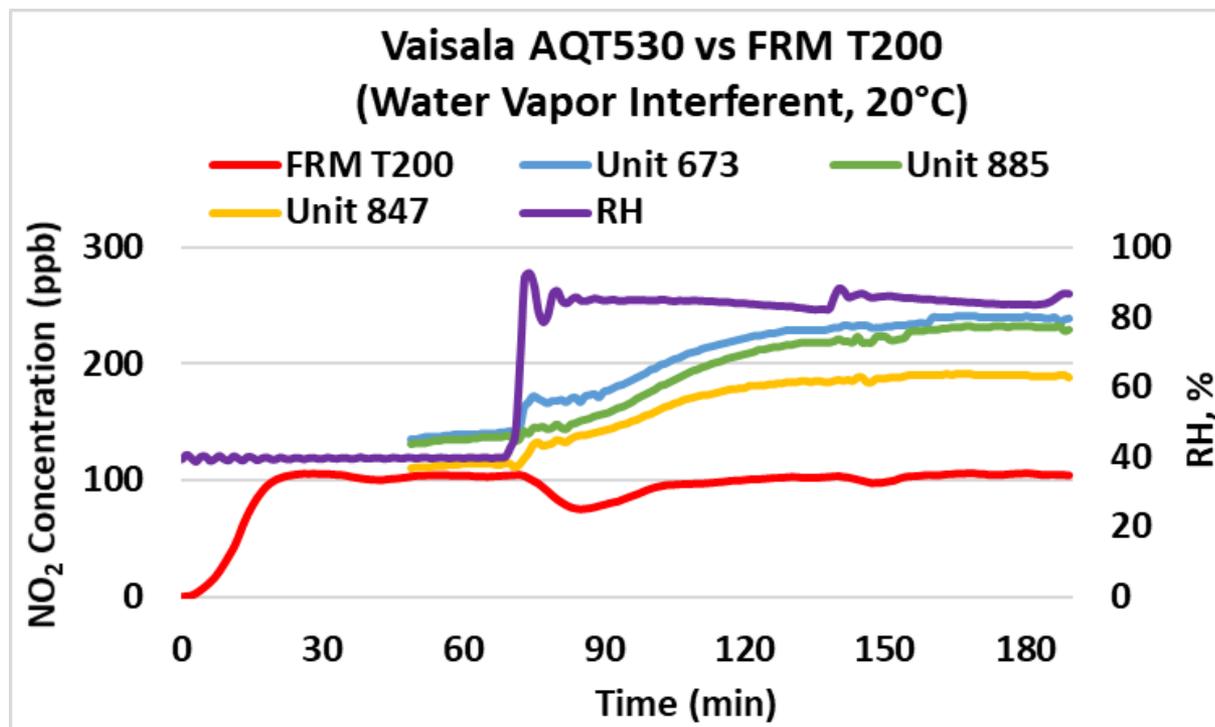
In the laboratory, the effect of O₃ interferent is evaluated by exposing sensors to 500 ppb of O₃ at 20°C and 40% RH while holding the NO₂ concentrations at 100 ppb. As shown in the figure, the FRM T200 and the sensors maintained their readings as the O₃ concentration increased to 500 ppb.

SO₂ Interferent: Vaisala AQT530 vs FRM T200 (NO₂)



In the laboratory, the effect of SO₂ interferent is evaluated by exposing sensors to 500 ppb of SO₂ at 20°C and 40% RH while holding the NO₂ concentrations at 100 ppb. As shown in the figure, the FRM T200 and the sensors maintained their readings as the SO₂ concentration increased to 500 ppb.

Water Vapor Interferent: Vaisala AQT530 vs FRM T200 (NO₂)



In the laboratory, the effect of water vapor interferent is evaluated by exposing sensors to 20,000 ppm of water vapor, which is corresponding to the water content at 20°C and 85% RH, while holding the NO₂ concentrations at 100 ppb. As shown in the figure, the FRM T200 maintained its NO₂ readings at 100 ppb as RH increased from 40% to 85% while the sensors' NO₂ readings increased as RH increased.

Discussion: NO₂

- **Accuracy:** The three Vaisala AQT530 sensors showed accuracy ranged from 61.8% to 89.9%.
- **Precision:** The three Vaisala AQT530 sensors exhibited high precision during all tested NO₂ conc., T, and RH conditions.
- **Intra-model variability:** Moderate NO₂ measurement variations were observed among the three Vaisala AQT530 sensors at 20°C and 40% RH.
- **Data recovery:** Data recovery for NO₂ measurements was 96.4%, 96.1%, and 98.5% for Units 673, 885, and 847, respectively.
- **Baseline:** At all conditions, FRM T200 NO₂ instrument baseline was ranging from 0 to 5.4 ppb, while the sensors' baseline was ranging from 3.4 to 333 ppb; high sensor baselines were observed at 35°C.
- **Response time:** Response time could not be studied due to the system design of the chamber system. With a 1.6 m³ chamber volume and the max gas flow of 20 LPM, it was not possible to reach a high pollutant concentration within a short time.
- **Linear Correlation:** The three Vaisala AQT530 sensors showed very strong correlation/linear response with the corresponding FRM T200 NO₂ measurement data ($R^2 > 0.96$) except for the NO₂ concentration ramping test at 35°C and 65% RH.
- **Interferents:** The three Vaisala AQT530 sensors were inert to most interferents (i.e. O₃, NO, CO₂, SO₂ and CO) at 20°C and 40% RH. The sensors' NO₂ readings increased as RH increased from 40% to 85%.

Discussion: NO₂

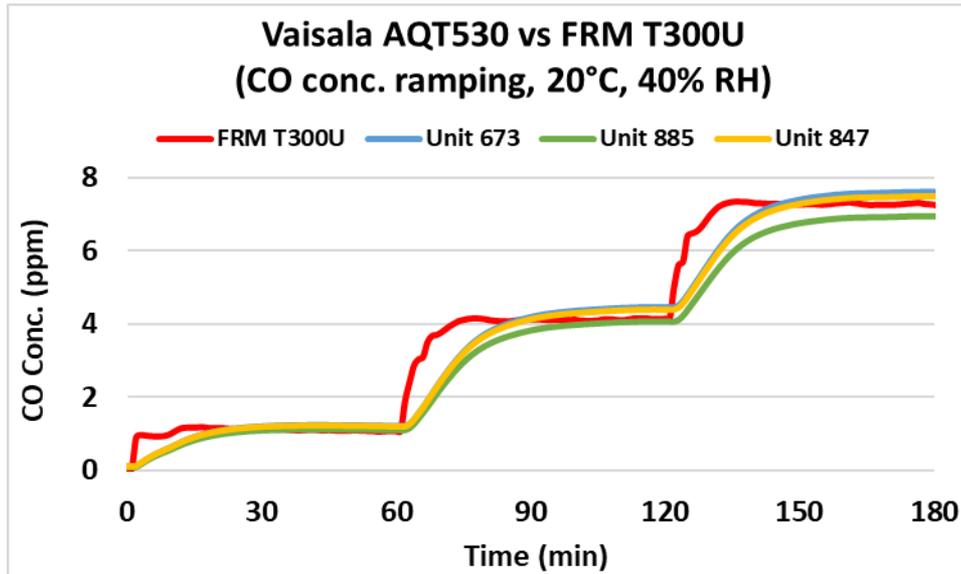
- **Measurement duration:** Vaisala AQT530 sensors report 1-min averaged values.
- **Measurement frequency:** Vaisala AQT530 sensors report 1-min averaged values. The obtained data was used as-is for calculation of statistics (e.g. data recovery, intra-model variability, mean, accuracy, precision), but condensed into 5-minute averages for linear correlation studies against the FRM T200.
- **Sensor contamination and expiration:** Prior to the laboratory evaluation, the Vaisala AQT530 sensors were tested in the field for two months. The NO₂ laboratory studies lasted for about 24 days with intermittent non-operating periods and a storage period of ~ 11 months. For NO₂ measurements, all three Vaisala AQT530 sensors maintained their functionalities and operated normally throughout the duration of the testing.
- **Concentration range:** 0-2 ppm NO₂ concentration as suggested by the manufacturer. During the laboratory evaluation, the Vaisala AQT530 sensors were challenged with NO₂ concentrations up to 200 ppb.
- **Climate susceptibility:** During the lab studies, the sensors NO₂ readings increased as RH increased; the sensors' overestimation increased as RH and T increased.
- **Response to loss of power:** Vaisala AQT530 sensors were powered through the entirety of the lab tests.

CO

1. **FRM T300U vs Vaisala AQT530**
2. **Accuracy, data recovery and intra-model variability**
3. **Precision**
4. **Climate susceptibility**
5. **Interferents**
6. **Discussion**

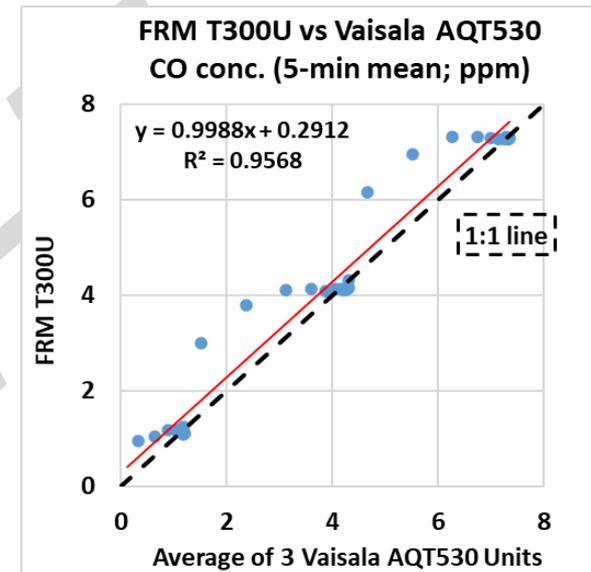
Note: The Vaisala sensors have an upper measurement limit of 10 ppm, so the steady-state periods examined were 1, 4 and 7 ppm CO as the low, medium and high CO concentrations, respectively.

Vaisala AQT530 vs FRM T300U (CO)



- The sensors tracked the CO concentration variations recorded by FRM T300U instrument
- Overall, the sensors slightly overestimated the CO concentration as recorded by the FRM T300U instrument

Coefficient of Determination



- The Vaisala AQT530 sensors showed very strong correlations with the corresponding FRM T300U CO conc. ($R^2 > 0.95$)

Accuracy: Vaisala AQT530 vs FRM T300U (CO)

- Accuracy (20°C and 40% RH)

Steady State (#)	Sensor Mean (ppm)	FRM T300U (ppm)	Accuracy (%)
1	1.2	1.1	91.4
2	4.3	4.1	96.3
3	7.3	7.3	99.2

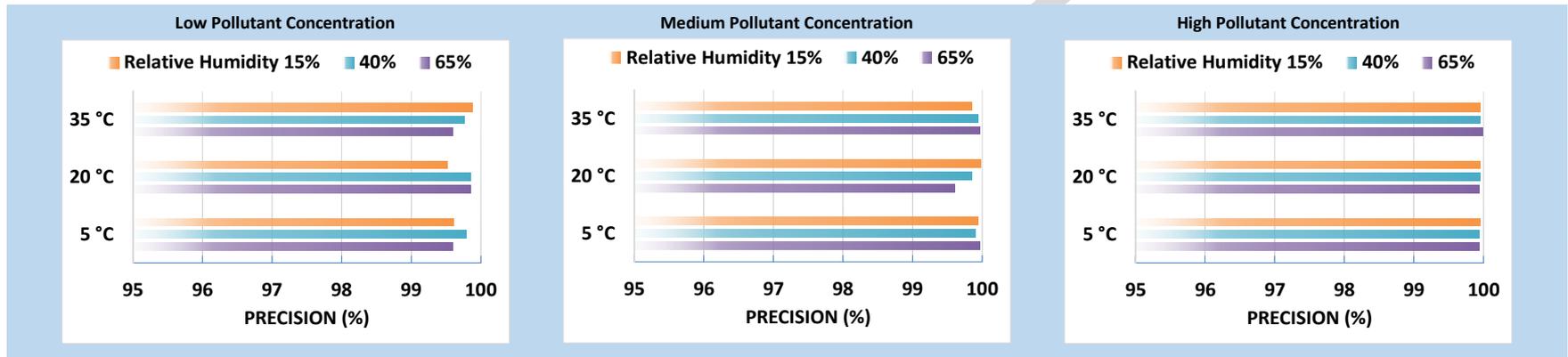
- Accuracy of the three Vaisala AQT530 sensors ranged from 91.4% to 99.2%. Overall, the sensors slightly overestimated the FRM T300U measurements at all CO concentrations at 20°C and 40% RH.

Vaisala AQT530 Data Recovery and Intra-model Variability

- Data recovery for CO measurements was 100% for all units
- Low CO concentration variations were observed between the three units at 20°C and 40% RH at low, medium and high CO concentrations as measured by the FRM T300U.

Precision: Vaisala AQT530 vs FRM T300U (CO)

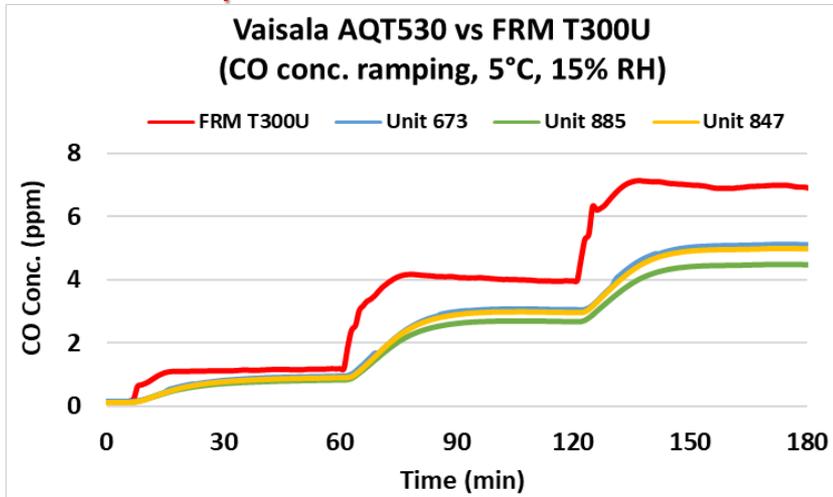
- Precision (Effect of CO conc., temperature and relative humidity)



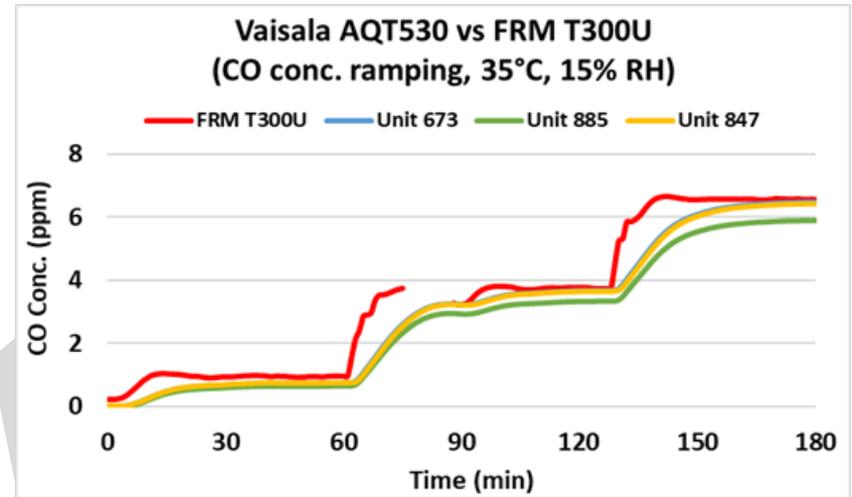
- Overall, the three Vaisala AQT530 sensors showed high precision for all combinations of CO conc., T, and RH.

Climate Susceptibility: Vaisala AQT530 (CO)

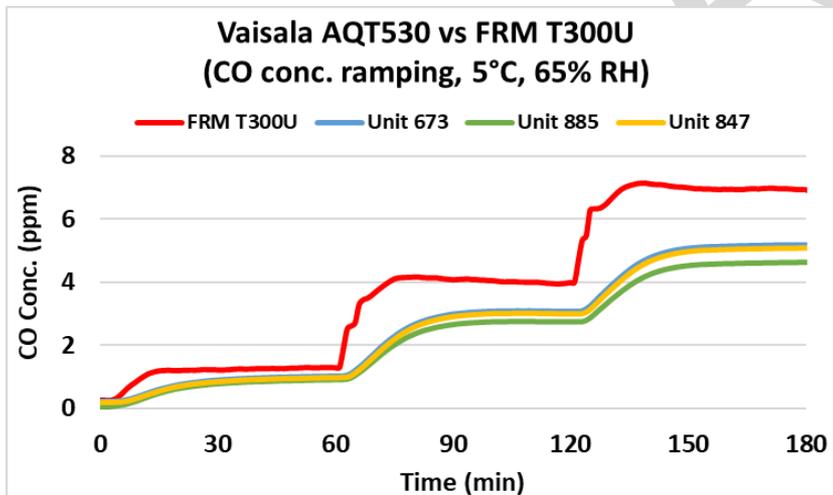
Low Temp-Low RH



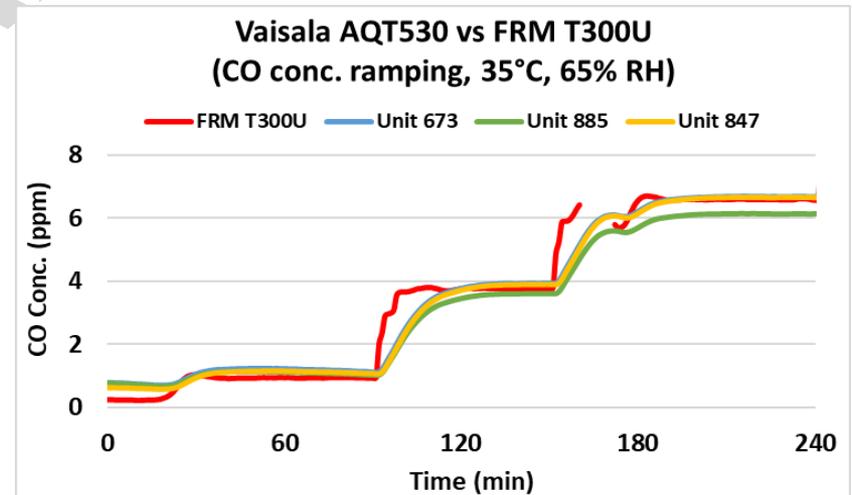
High Temp-Low RH



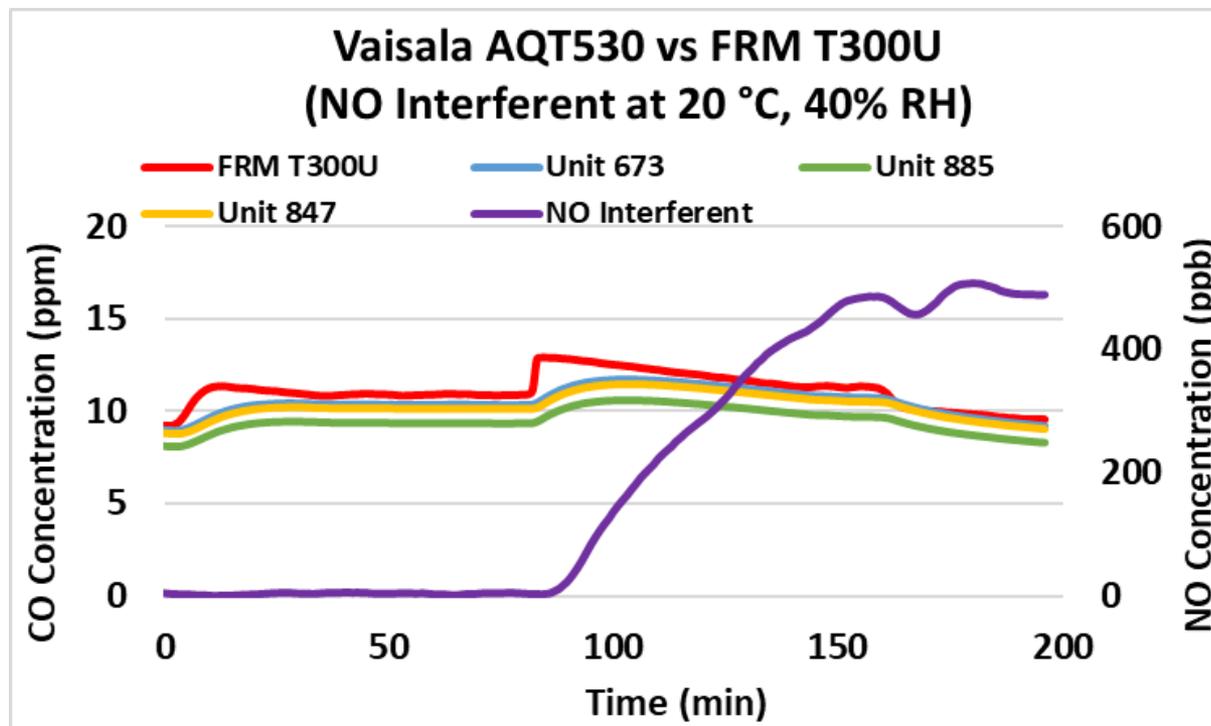
Low Temp-High RH



High Temp-High RH

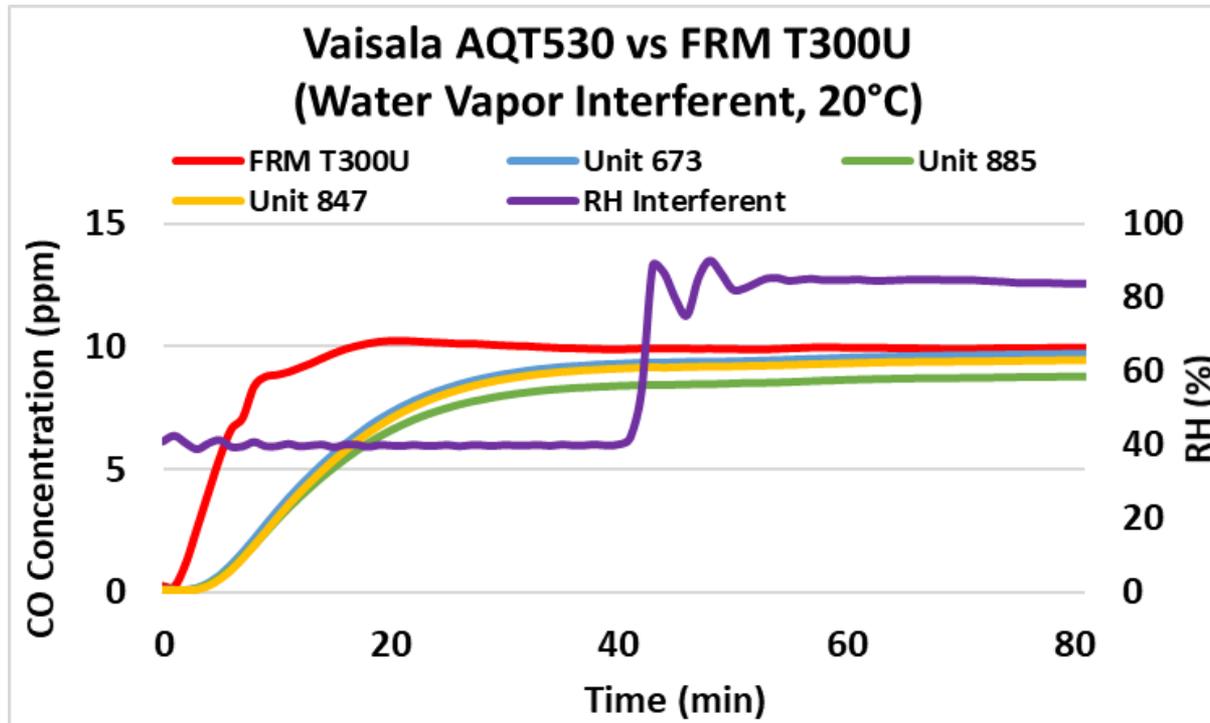


NO Interferent: Vaisala AQT530 vs FRM T300U (CO)



In the laboratory, the effect of NO interferent is evaluated by exposing sensors to 500 ppb of NO at 20 °C and 40% RH while holding the CO concentrations at 10 ppm. As shown in the figure, the FRM T300U and the sensors maintained their readings as the NO concentration increased to 500 ppb.

Water Vapor Interferent: Vaisala AQT530 vs FRM T300U (CO)



In the laboratory, the effect of water vapor interferent is evaluated by exposing sensors to 20,000 ppm of water vapor, which is corresponding to the water content at 20°C and 85% RH, while holding the CO concentrations at 10 ppm. As shown in the figure, the FRM T300U and the sensors maintained their CO readings as RH increased from 40% to 85%.

Discussion: CO

- **Accuracy:** The three Vaisala AQT530 sensors showed accuracy ranged from 91.4% to 99.2%.
- **Precision:** The three Vaisala AQT530 sensors exhibited high precision during all tested CO conc., T, and RH conditions.
- **Intra-model variability:** Low CO measurement variations were observed among the three Vaisala AQT530 sensors at 20°C and 40% RH.
- **Data recovery:** Data recovery for CO measurements was 100% for all units
- **Baseline:** At all conditions, FRM T300U CO instrument baseline was ranging from 0.02 to 0.30 ppm, while the sensors' baseline was ranging from 0 to 0.43 ppm.
- **Response time:** Response time could not be studied due to the system design of the chamber system. With a 1.6 m³ chamber volume and the max gas flow of 20 LPM, it was not possible to reach a high pollutant concentration within a short time.
- **Linear Correlation:** The three Vaisala AQT530 sensors showed very strong correlation/linear response with the corresponding FRM T300U CO measurement data ($R^2 > 0.95$).
- **Interferents:** The three Vaisala AQT530 sensors were inert to both NO and water vapor interferents. The sensors' CO readings remained constant as the interferent concentrations increased.

Discussion: CO

- **Measurement duration:** Vaisala AQT530 sensors report 1-min averaged values for the duration of all experiments.
- **Measurement frequency:** Vaisala AQT530 sensors report 1-min averaged values. The obtained data was used as-is for calculation of statistics (e.g. data recovery, intra-model variability, mean, accuracy, precision), but condensed into 5-minute averages for linear correlation studies against the FRM T300U.
- **Sensor contamination and expiration:** Prior to the laboratory evaluation, the Vaisala AQT530 sensors were tested in the field for two months. The CO laboratory studies lasted for about four weeks with intermittent non-operating periods and a storage period of ~ 11 months. For CO measurements, all three Vaisala AQT530 sensors maintained their functionalities and operated normally throughout the duration of the testing.
- **Concentration range:** 0-10 ppm CO concentration as suggested by the manufacturer. During the laboratory evaluation, the Vaisala AQT530 sensors were challenged with CO concentrations up to 7 ppm.
- **Climate susceptibility:** During the lab studies, the sensors CO readings were higher at high T.
- **Response to loss of power:** Vaisala AQT530 sensors were powered through the entirety of the lab tests.